Forest Service Aerial Spray Computer Model - FSCBG 4.2 User Manual Extension

Agriculture

Forest Service

Forest Pest Management

Davis, CA

FPM 93-17
April 1993

FPM 93-17
(CDI Technical Note 93-05)
April 1993

Forest Service Aerial Spray Computer Model - FSCBG 4.2 User Manual Extension

Prepared by:

Milton E. Teske and
Tom Curbishley

Continuum Dynamics, Inc.
P.O. Box 3073
Princeton, NJ 08543

Contract No. 53-04H1-9-0510

Prepared for:

USDA Forest Service
Forest Pest Management
2121C Second Street
Davis, CA 95616
PH (916)758-4600
FAX (916)757-8383

INTRODUCTION

FSCBG 4.0 was released to the user community on January 15, 1992. Since then, numerous improvements have been made as needs were encountered by Continuum Dynamics, Inc. and other users. We have also been involved in programming additional features into the model. All of the changes to date have been embodied into FSCBG 4.2, including:

1. Data export to commercial graphics programs or data packages
2. DOS operating system interface for file names
3. Interactive libraries
4. Separate mass size library entries for small drop sizes
5. Mass size distribution manipulation
6. Evaluation of Swath Width
7. Calculation of Total Accountancy of released material
8. Pie charts and bar charts for Total Accountancy results
9. Font selection for graphical output
10. Saving plotting parameters
11. Collection efficiency added to discrete receptors
12. Net radiation index computation

This User Manual Extension summarizes the above features, and is a companion document to the FSCBG 4.0 User Manual (Teske and Curbishley 1991). It is assumed in all that follows that the reader is familiar with the User Manual. As before, comments and suggestions regarding FSCBG and this manual extension may be forwarded to:

FSCBG System Manager
USDA Forest Service FPM
2121C Second Street, Suite 102
Davis, CA 95616
(916) 758-4600
(916) 757-8383 fax

or to:

FSCBG User Group
Continuum Dynamics, Inc.
P. O. Box 3073
Princeton, NJ 08543
(609) 734-9282
(609) 734-9286 fax

FSCBG 4.0 USER MANUAL CHANGES

Additional clarification is in order for the procedures to invoke to achieve Graphics Hardcopy, establish good Receptor Grid Geometry, and recover nonvolatile pesticide deposition with nonvolatile tank mix additives.

Graphics Hardcopy Destination:

```
EC Setup>H/C Dest

                Graphics Hardcopy Destination

              A-Std Output
              B-Disk File
              C-Comm 1
              D-Comm 2
```

The available graphics destinations are displayed. The selection of Standard Output will send graphical results to the screen. The selection of Disk File will write results into a disk file. The selection of Comm 1 or Comm 2 will send graphical results to the display devices connected to the personal computer communication (serial) ports.

Hardcopy Plot:

Selection of Hardcopy Plot (in various menus) gives the user the option of typing in a filename (assuming Disk File has been chosen as the appropriate hardcopy destination in Setup). If, at this point, the user types in LPT1 as the filename, the plot will be sent directly to the hardware device attached to the parallel printer port. If the plot is being sent to a PostScript printer, PostScript must have also been selected in Setup. If the user types in a filename, or chooses to keep the default filename that appears, a disk file will be created with the appropriate plot information in it. After exiting FSCBG, the user can then send the plot to a hardcopy device by using either the DOS COPY or PRINT commands (for example, COPY filename LPT1). Some users have encountered a problem with some PostScript printers; in these cases the User Group will supply an additional program that filters the plot file through the communications port to recover the printed plot.

Receptor Geometry:

As a general rule-of-thumb, if the user is attempting to predict deposition on a target area, a receptor should be placed directly under each flight line, and at least one receptor should be placed between each flight line. Additional receptors may be added if the swath width exceeds 100 feet. The reason for this recommendation is that drops larger than 150 micrometers will generally fall near the spray swath, depending of course on meteorological conditions. If enough receptors are not placed under the aircraft, the deposition there will be recovered incorrectly.

An example of a good receptor grid for measuring deposition on-target and drift downwind would be to place a receptor under each flight line and one or more receptors (placed uniformly across the swath width) between each flight line. This pattern should be continued downwind for a given distance, then every 100 feet downwind, then every 200 feet downwind, and then every 500 feet downwind for as far as the user expects the material to drift.

If the deposition appears to be unrepresentative on target, the user should examine the Near Wake plot of Continuous Deposition. This plot will indicate what a single swath should look like, and should enable the user to reposition receptors to describe the deposition pattern correctly.

A future release of FSCBG will include an option to permit the program to try a first-cut at the Receptor Grid Geometry, given the Source Geometry specified by the user.

Nonvolatile Deposition:

If the user wishes to recover the nonvolatile pesticide deposition from a tank mix that contains nonvolatile additives as well, several input modifications must be made before running FSCBG. Suppose, for example, that the nonvolatile pesticide fraction is 0.02 but that the total nonvolatile fraction (including the nonvolatile tank mix additives) is 0.05. The nonvolatile fraction entered in the Spray Material menu as the "Volatile Fraction of Carrier" must preserve the tank mix fraction, since this directly affects evaporation (in this example the entry would be 0.95). A Results selection of nonvolatile deposition would recover the entire nonvolatile prediction, and not just the nonvolatile pesticide contribution. The best way around this is to modify the "Emission Rate" (in the Source Geometry menu) to reflect the difference between the pesticide and total nonvolatile fractions. In this example that difference is the ratio of 0.02 to

0.05 or 0.4. Thus, the emission rate entered should be 40 percent of the actual emission rate. The results predicted by FSCBG would then accurately reflect the nonvolatile pesticide deposition.

The user should be alert here, however: if the total deposition is desired, the actual emission rate must be entered in the Source Geometry menu. This change of input will not require FSCBG to rerun the dispersion module, since all deposition predictions by FSCBG are stored in normalized form.

1. DATA EXPORT

FSCBG now enables export of computed results into a data file, for later import by the user into commercial data manipulation or graphics packages such as Lotus 1-2-3 or Harvard Graphics. The Setup menu has been modified:

```
E Setup

              Machine-Specific Setup

          A-Device for Graphics Display      none
          B-Device for Graphics Hardcopy     none
          c-Graphics Hardcopy Destination
          D-Graphics Display Color Option    Color
          e-Graphics Hardcopy Color Option
          F-Delimiter Character for Export   <space>
          G-Save Setup
```

New menu option F permits the user to specify a single character representing the delimiter between columns of exported data. The default is a single space (" "). Some graphics packages require a TAB character (which, when displayed here, will look like "<tab>"). Unprintable delimiters will be displayed as "^" followed by a letter; printable delimiters will be displayed by the printable character. If the delimiter will never change, the user should Save Setup after selecting the delimiter.

All of the options (in various menus) to "Export Results to Data File" are now active. These include the following:

1. Near Wake Continuous Deposition, with a two-column format of horizontal distance (in user-selected length units) and deposition (in user-selected deposition units).

2. Near Wake Vertical Flux profile, with a two-column format of vertical distance and flux.

3. Near Wake Drift Fraction time history, with a two-column format of time (in seconds) and drift fraction (no units).

4. Swath Width Coefficient of Variation, with a two-column format of lane separation (in user-selected length units) and COV (no units).

5. Swath Overlap Pattern, with a two-column format of horizontal distance and deposition.

6. Receptor Grid results, with a four-column format of grid X, Y and Z locations and dosage, concentration or deposition.

7. Discrete Receptor results, with a four-column format of X, Y and Z discrete locations and dosage, concentration or deposition.

8. Total Accountancy results, with a five-column format of time (in seconds), material fraction aloft, fraction deposited on the ground, fraction deposited in the canopy, and vapor fraction aloft.

The user is expected to remember the units of the column results saved in the export files, as they are not written into the file.

When export is invoked, the user will be presented with a default name for the file. This name will be uniquely determined from the Family Name and extensions of Wxy for Near Wake files, Dxy for Dispersion files, and Txy for Total Accountancy files. "xy" are the numbers 01, 02, etc. as needed. This notation is consistent with the Near Wake trajectory files (Bxy) and the plot files (Pxy). The user will also have to keep track of the information each file contains.

2. DOS INTERFACE

FSCBG now permits the user to access the operating system to recover Family Names. The Files menu has been modified:

```
A Files

                Data File/Family Operations

              A-Open ...
              B-Save As ...
              C-Import FSCBG 3.XX Data
```

When options A and B are invoked, the current directory is examined, and all applicable DAT file names are displayed on the screen (even those files not generated by FSCBG). The user may move through the list with the arrow keys to locate the file desired. A < return > either opens the file or saves results into the file. Alternately, the user may examine the list, then backspace to remove any file name present on the second line on the screen, and enter an appropriate file name.

3. INTERACTIVE LIBRARIES

FSCBG now includes interactive libraries. The libraries that exist in the program are:

FSCBG.ACL	Aircraft
FSCBG.CNL	Canopy
FSCBG.MSL	Mass Size Distribution
FSCBG.MTL	Meteorological Data
FSCBG.RGL	Receptor Geometry
FSCBG.SGL	Source Geometry
FSCBG.SML	Spray Material
FSCBG.SSL	Spray System

Default entries for these libraries are provided on the distribution diskette. The binary structure of these libraries has been changed from FSCBG version 4.0; consequently, the user should copy the new FSCBG.ACL and FSCBG.MSL libraries over the old ones distributed with FSCBG version 4.0.

Each of these libraries is accessed similarly. Each now contains the ability to name the contents of their entries. When the user invokes any library, these names are displayed in alphabetical order. At this point the third line on the screen reads:

```
? help  <esc> go back (v)iew (u)se (a)dd (d)elete (g)oto
```

where:

- v permits viewing of the entry (< return > also does this)
- u indicates that the user wishes to transfer the current library entry into the program
- a indicates that the user wishes to add the current program data to the library
- d indicates that the user wishes to delete the current library entry from the library
- g permits the user to jump to a specific location in the library name display

With the options u , a , and d the third line on the screen will then read:

```
? help  <esc> cancel  (y)es (n)o
```

where:

y invokes the intended operation
n cancels the intended operation (< esc > also does this)

The user should manipulate all library entries with caution, as each library can now become very personalized, and keep the distribution diskette available to recover the original libraries if necessary.

To accommodate the ability to name the entries in the library, changes are necessary in the following menus:

Receptor Geometry:

```
BC Data>Recep

              Receptor Geometry

            A-Name
            B-Receptor Grid
            C-Discrete Receptor(s)                    1
            D-Receptor Library
```

Canopy Description:

```
BD Data>Canopy

              Canopy

            A-Name
            B-Canopy Data
            C-Canopy Library
```

Spray System:

```
BF Data>Spray Sys

              Spray System

            A-Name
            B-Nozzle Forward Location(s)              .0 m
            C-Nozzle Horiz/Vert Location(s)           17
            D-Spray System Library
```

Spray Material:

```
BG Data>Spray Mat

                Spray Material

            A-Name
            B-Material Half-Life                Infinite
            C-Density of Carrier                  .9970 g/cm3
            D-Carrier Type                       water
            E-Volatile Fraction of Carrier        .9400
            F-Mass Size Distribution
            G-Minimum Drop Diameter               5.00 mic
            h-Physical Constants
            I-Spray Material Library
```

Mass Size Distribution:

```
BGE Data>Spray Mat>Mass Size Dist

                Mass Size Distribution

            A-Name
            B-Specification                 average diameter
            C-Mass Size Distribution                  11
            D-Mass Size Distribution Library
```

Source Geometry:

```
BH Data>Src Geom

                Source Geometry

            A-Name
            B-Spraying Speed                    17.90 m/s
            C-Release Height                    23.60 m
            D-Emission Rate                      5.00 gal/ac
            E-Swath Width                       18.30 m
            F-Source Location(s)                    9
            G-Add Regularly Spaced Sources
            H-Source Geometry Library
```

Meteorological Data:

```
BI Data>Met

                Meteorological Data

              A-Name
              B-Vortex Decay Coefficient              .5600 m/s
              C-Surface Pressure                   1013.00 mb
              D-Net Radiation Index                   1.00
              E-Open Terrain                             8
              F-Within Canopy                            7
              G-Advanced Override Inputs
              H-Compute Net Radiation Index
              I-Meteorological Data Library
```

When the u option is selected for the Mass Size Distribution library, the third line on the screen will read:

```
? help  <esc> cancel  (y)es (n)o (c)urvefit
```

with an extra option for curve fitting the data.

4. SMALL DROP SIZE LIBRARY ENTRIES

The Mass Size Distribution library now contains the unmanipulated data found in Skyler and Barry 1991, in addition to 21 distributions with drop sizes below 34 microns (from Yates and Cowden 1987), identified by an asterisk (*) after the material information on the entry name. All data in the library adds to a total mass fraction of 1.0, except for the drop size data below 34 microns, which represents only a portion of more complete distributions. The entry name includes the airstream angle (deg) or rpm for the nozzle, and the speed of the aircraft (mph).

5. MASS SIZE MANIPULATION

Mass Size Distribution library data may be manipulated by one of two techniques:

y all entries in the default library give the size classes by upper diameter. When the user selects an entry, FSCBG compresses the entry to 16 drop sizes by combining in pairs from the largest drop sizes down to the smallest. FSCBG then converts the upper diameter specification to average diameter specification by using the volume-average technique suggested by Herdan 1960. After these manipulations the user will again be asked to accept the resulting distribution.

c curve fit leads to a new menu:

```
BGFDU Data>Spray Mat>Mass Size Dist>Library>Crv Fit

              Create Drop Categories by Curvefit

          A-Minimum Drop Diameter              56.00 micron
          B-Maximum Drop Diameter             414.00 micron
          C-First Drop Category Increment      23.87 micron
          D-Number of Categories                  16
          E-Generate Categories & Go Back
```

FSCBG now contains an algorithm to curve fit the entered distribution with a "root/normal" least squares technique (Simmons 1977 and Teske and Barry 1992). This technique examines the current distribution and generates a consistent distribution depending upon the user entries in the above menu. The values initially present in this menu are extracted from the current distribution. The Minimum and Maximum Drop Diameters are those present in the current distribution. An assumption of 16 drop sizes recovers a uniform Drop Category Increment as shown. The algorithm permits a small value of First Drop Category Increment, and will generate smoothly increasing Increments to achieve the required Maximum Drop Diameter within the desired number of drop size categories. Option E is invoked to activate the algorithm. Several minutes may be needed to generate the results, which must again be accepted by the user.

6. SWATH WIDTH

FSCBG now permits the user to compute the anticipated Swath Width of the deposition generated from a Near Wake computation. The new Near Wake Results menu becomes:

```
DE Results>Wake

              Near Wake Plots

          A-Select Drop Category for Plots          1
          B-Select Dispersion Units         drops / sq m
          C-Select Dispersion Contrib       non-volatile
          D-Select Vertical Flux Position          .0 m
          E-Plot Mean Drop Trajectories
          F-Plot Mean+Std Dev Trajectories
          G-Continuous Deposition
          H-Vertical Flux Profile
          I-Drift Fraction Time History
          J-Swath Width
          K-Swath Overlap Pattern
```

Option J -- Swath Width will generate a plot of Coefficient of Variation as a function of Lane Separation. A COV of 0.3, or a local minimum in the computed curve, will recover the Swath Width, following the discussion developed in Teske et al. 1990.

Option K -- Swath Overlap Pattern will generate a three-flight-line deposition pattern as a function of distance across the swath.

7. TOTAL ACCOUNTANCY

FSCBG now permits the additional Results option of computing Total Accountancy. Total Accountancy recovers a calculation of the time history of the spray material released from the nozzles, in four categories: material deposited on the ground, material deposited in the canopy (if a canopy exists), material evaporated (if evaporation occurs), and material still aloft. The revised menu becomes:

```
D Results

                Results

              A-Preview Plots
              B-Meteorological Plots
              C-Evaporation Plots
              D-Canopy Plots
              E-Near Wake
              F-Dispersion
              G-Total Accountancy
```

Option G leads to the menu:

```
DG Results>TotAc

                Total Accountancy Results

              A-Select Dispersion Contrib    total non-gaseous
              B-Plot Contribution vs Time
              C-Pie Chart of Final Results
              D-Bar Chart of Final Results
              E-Append Results to Print File
              F-Export Results to Data File
```

Total Accountancy may be invoked for either the total material released, or its nonvolatile portion (if evaporation is present).

8. PIE CHARTS AND BAR CHARTS

The Total Accountancy menu is:

```
DG Results>TotAc

                Total Accountancy Results

            A-Select Dispersion Contrib    total non-gaseous
            B-Plot Contribution vs Time
            C-Pie Chart of Final Results
            D-Bar Chart of Final Results
            E-Append Results to Print File
            F-Export Results to Data File
```

In addition to plotting the time history of Total Accountancy (with option B), a pie chart (option C) and a bar chart (option D) of the final results may also be obtained. A typical time history plot is shown in Figure 1.

The pie chart displays the final distribution of material in a pie format (see Figure 2). Four slices of the pie are shown, representing material still aloft (Aloft), evaporated (Vapor), deposited on the ground (Ground), and deposited in the canopy (Canopy). All four slices are displayed even if they have a value of zero; in other words, material evaporated and deposited in a canopy are shown as zero if there is no evaporation or canopy, respectively.

The bar chart is similar to the pie chart (see Figure 3), but displays the final distribution of material as vertical bars whose heights represent the fraction of material in each category (material still aloft, evaporated, deposited on the ground, and deposited in the canopy). Each bar is labeled with the category and percent contribution.

The pie chart Plot Format contains a "Slice Label Character Height" that sets the height of the characters within the body of the pie chart, and an "X Label Character Height" that sets the height of the characters that form the chart label. The bar chart percentages key to the X Axis "Tic Label Character Height" entry.

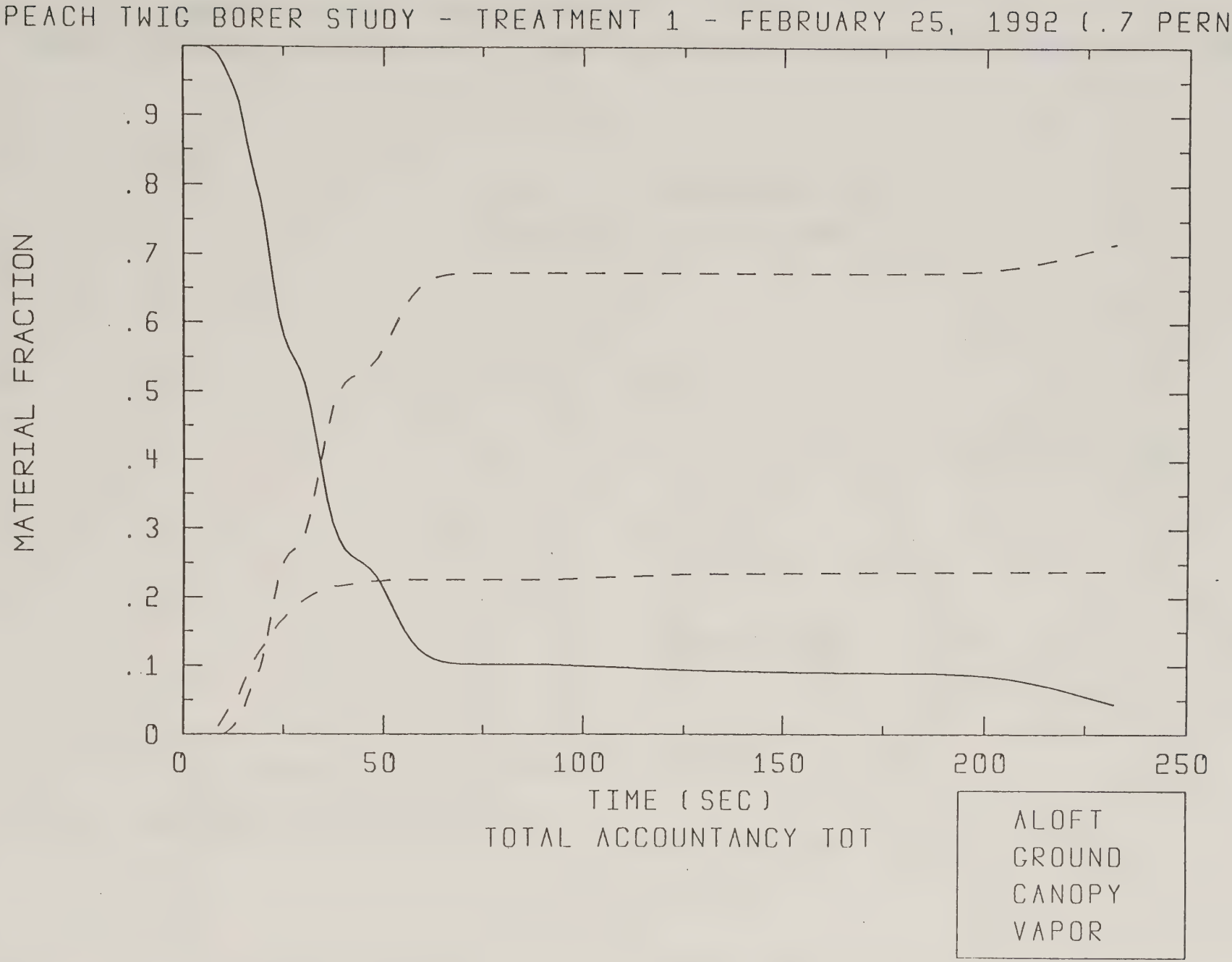

Figure 1. Example time history of Total Accountancy. The curves summarize the relative amount of spray material fraction: Aloft -- solid line; Ground -- upper dashed line; Canopy -- lower dashed line; Vapor -- no line.

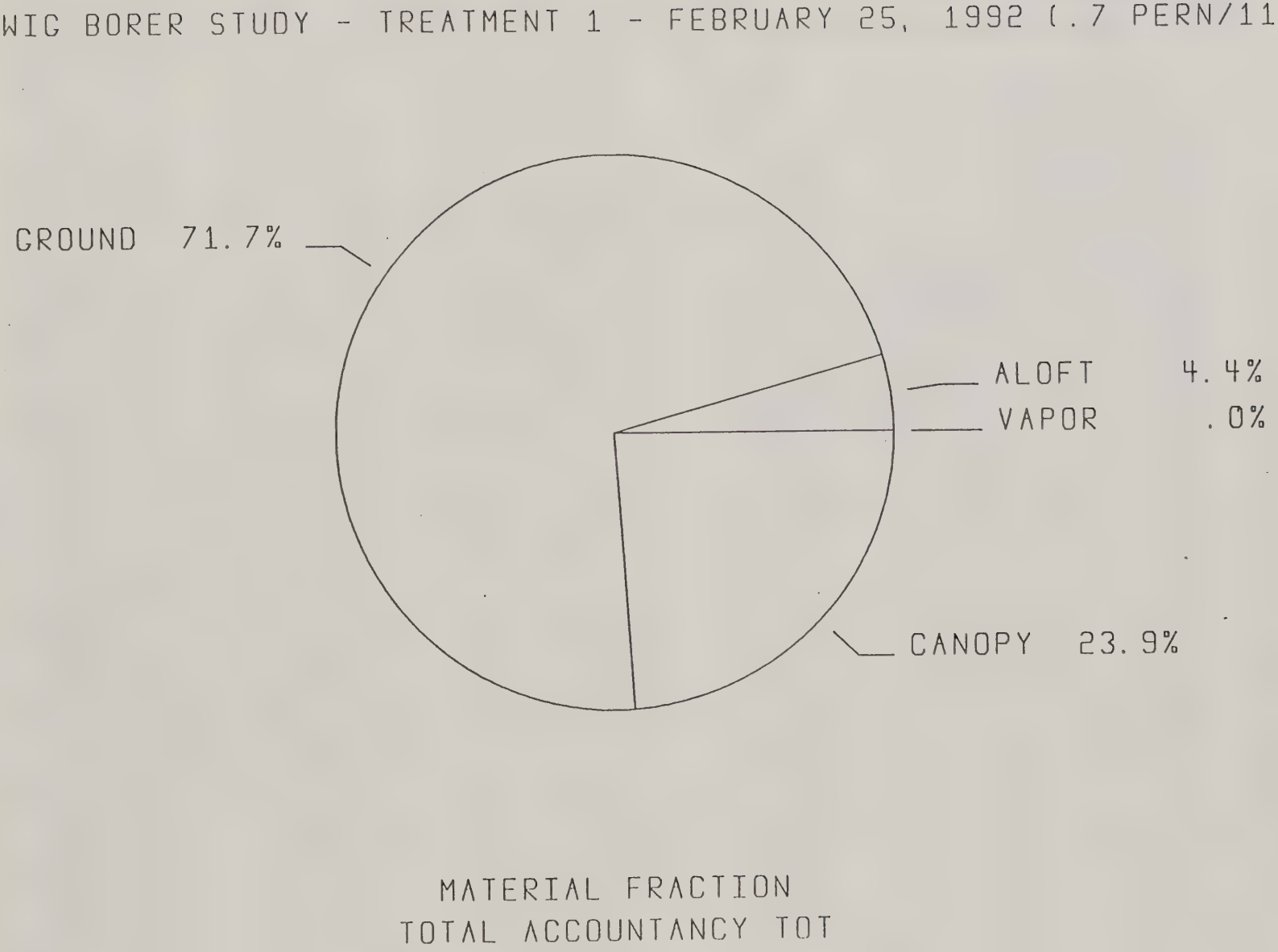

Figure 2. Example Total Accountancy pie chart of final results, displaying environmental fate of spray material in percentage of material fraction.

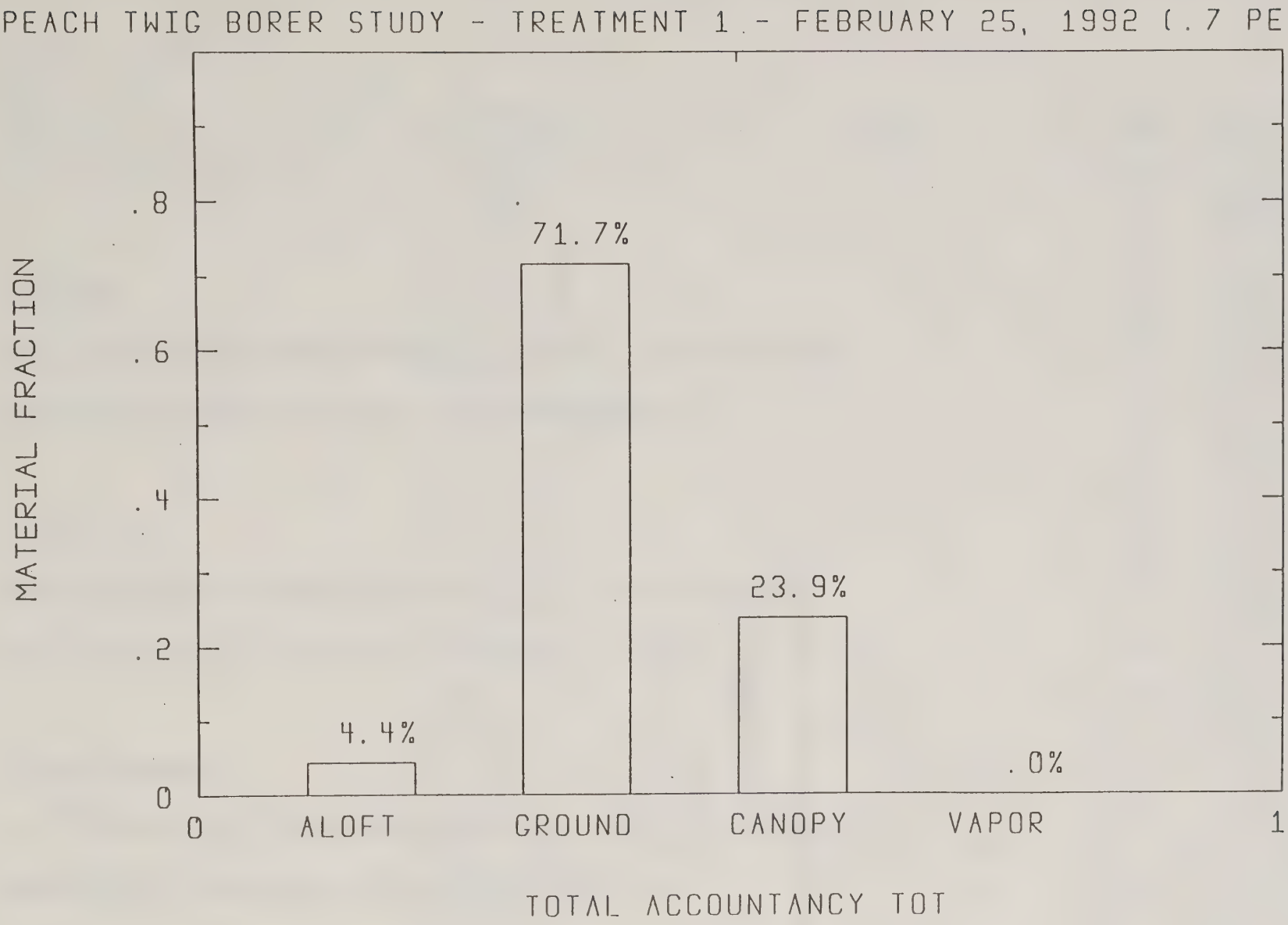

Figure 3. Example Total Accountancy bar chart of final results, displaying environmental fate of spray material in percentage of material fraction.

9. FONT SELECTION

FSCBG plots can now be displayed in three alternative fonts: Times Roman, Courier, and Avalon. These fonts dress up plots and make them look more professional; however, because of their complexity, they cause plots to take longer to complete.

The Plot Format menu has been expanded to accommodate the selection of these new fonts:

```
  Plot Format

A-X Axis
B-Y Axis
C-Legend
D-Margins
E-Font
F-Save Settings
```

Option E displays the available fonts:

```
  Select Text Font

A-default
B-Times Roman
C-Courier
D-Avalon
```

The original font is retained by FSCBG and is identified as the default font (option A). Font characteristics are shown in Figure 4. Because of the construction characteristics of the new fonts, they will appear smaller than the default font set to the same size. The user may find it necessary to increase the character heights of the titles and labels when using one of the new fonts.

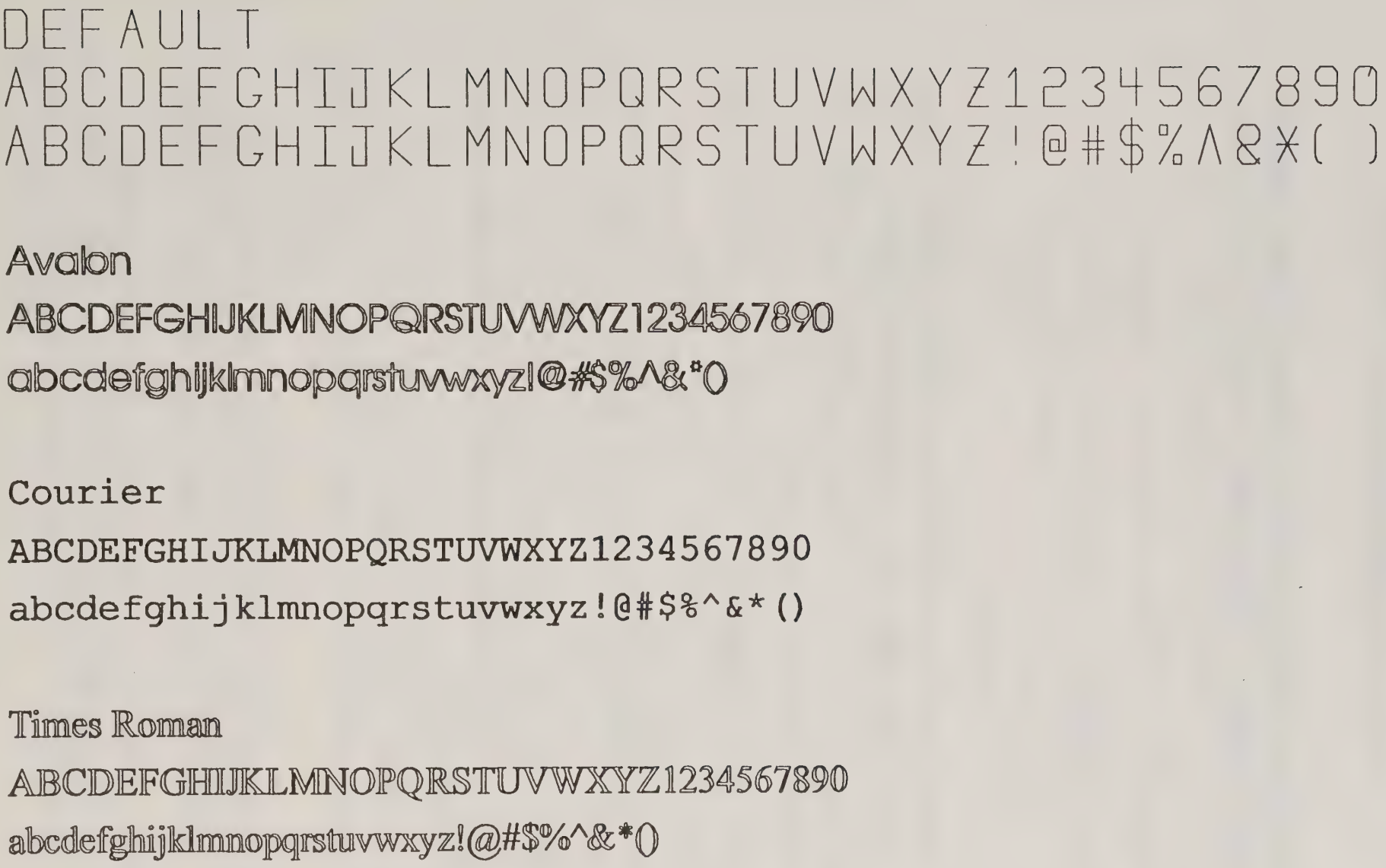

Figure 4. Font types available in FSCBG: default; Avalon; Courier; and Times Roman.

10. SAVING PLOTTING PARAMETERS

FSCBG now permits the user to save the plotting parameters (margins, character heights, scaling parameters, etc.) by invoking option F from the revised Plot Format menu:

```
  Plot Format

A-X Axis
B-Y Axis
C-Legend
D-Margins
E-Font
F-Save Settings
```

In response to this option FSCBG creates the file FSCBG.PFG and saves the current plotting information in it. Whenever FSCBG is invoked, the program will read this file and set the plot characteristics accordingly. If for some reason the user finds it necessary to return to the default settings, the easiest solution is to delete this file.

FSCBG now also permits the user to modify the height of the plot legend with option C in the Plot Format. This option leads to:

```
A-Legend Text
B-Legend/Title Character Height      .1500

Legend Text:
```

Option A permits the user to change the legend text, and option B, the legend character height.

11. DISCRETE RECEPTORS

FSCBG now expands the role and function of the discrete receptors by permitting them to acquire specific collector attributes. The discrete receptor menu now contains eight entries per receptor:

0. Receptor number (1 to 100) that always stays on the screen.
1. Collector Type:
    1: default flat card with 100 percent collection efficiency
    2: flat card or ribbon
    3: cylinder
    4: sphere
2. X receptor location
3. Y receptor location
4. Z receptor location (height)
5. X outward normal
6. Y outward normal
7. Z outward normal
8. Characteristic size: width of collector type 2, or diameter of types 3 and 4

The (X,Y,Z) outward normal values identify the receptor direction for collector types 2, 3 and 4. X and Y correspond to the Receptor Grid directions entered by the user; Z is vertically upward. For example, if collection is to take place on the top of a flat surface, the outward normals would be (0,0,1); if collection is to take place on the upwind side of the collector, and the wind is blowing left to right (minus X to plus X), the outward normals would be (-1,0,0).

Entries of (X,Y,Z) outward normals and characteristic size for collector type 1 are not used in FSCBG. Although collector types are entered with Real numbers, they are converted to Integer upon exit from the Discrete Receptor menu.

The tabulated values scroll horizontally to accommodate the extra columns of data. Pressing the left or right arrow keys will cause the table to shift left or right as the cursor reaches the edge of the display.

Collection efficiency is determined by evaluating a parameter involving the density of the spray material, its drop size and its velocity toward the collector, and interpolating within the experimental curves of May and Clifford 1967.

12. NET RADIATION INDEX

The Meteorological Data menu now appears as:

```
BI Data>Met

                Meteorological Data

          A-Name
          B-Vortex Decay Coefficient          .5600 m/s
          C-Surface Pressure                 1013.00 mb
          D-Net Radiation Index                 1.00
          E-Open Terrain                           8
          F-Within Canopy                          7
          G-Advanced Override Inputs
          H-Compute Net Radiation Index
          I-Meteorological Data Library
```

Option H permits the user to enter field data and let FSCBG compute Net Radiation Index appearing as option D. The new menu becomes:

```
BIH Data>Met>NetRad

                Compute Net Radiation Index

          A-Date (MMDDYY)                    090490
          B-Time (HHMM GMT)                    1705
          C-Cloud Cover                        15.0 %
          D-Cloud Height                     4000.0 ft
          E-West Longitude                    74.58 deg
          F-North Latitude                    40.35 deg
          G-Compute Index and Go Back
```

Options A and B enter the Date and Time of the field test, with the time referenced to Greenwich Mean Time (including the possible effect of Daylight Savings Time). Both Date and Time must include leading zeros where needed (for days under 10; for hours less than 10 am; and for minutes less than 10). The time is a 24-hour clock.

Option C enters the amount of cloud cover (in percentage) and option D estimates the cloud height. Options E and F position the field test location by entering the longitude (where west of Greenwich is positive) and latitude (where north of the equator is positive). Option G invokes the calculation and replaces Net Radiation Index with the computed value. If option G is not invoked, the calculation will not take place.

REFERENCES

Herdan, G. 1960. Small Particle Statistics. London: Buttersworths.

May, K. R. and R. Clifford. 1967. The impaction of aerosol particles on cylinders, spheres, ribbons and discs. *Annals of Occupational Hygiene* 10: 83-95.

Simmons, H. C. 1977. The correlation of drop-size distributions in fuel nozzle sprays. *Transactions of the ASME Journal of Engineering for Power* 99: 309-314.

Skyler, P. J. and J. W. Barry. 1991. Final report - compendium of drop size spectra compiled from wind tunnel tests. Report No. FPM 90-9. USDA Forest Service, Forest Pest Management, Davis, CA.

Teske, M. E. and J. W. Barry. 1992. Correlation of the USDA Forest Service drop size distribution data base. ILASS-Americas 92, 5th Annual Conference on Liquid Atomization and Spray Systems, San Ramon, CA. 157-161.

Teske, M. E. and T. B. Curbishley. 1991. Forest service aerial spray computer model FSCBG 4.0 user manual. Report No. FPM 91-1. USDA Forest Service, Forest Pest Management, Davis, CA.

Teske, M. E., D. B. Twardus and R. B. Ekblad. 1990. Swath width evaluation. Report No. 9034-2807-MTDC. USDA Forest Service, Technology and Development Center, Missoula, MT.

Yates, W. E. and R. B. Cowden. 1987. Data report of wind tunnel tests -- characterization of selected tank mixes and nozzles for drops less than 34 micron diameter. Report No. FPM-87-5. USDA Forest Service, Forest Pest Management, Davis, CA.